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Procedure		
	OBJET *(Subject)* : **LM2 performance test results**	**Ref :** LAT-TD-00616-01
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Change History log

PA	10 Dec 2001	Creation	G. Bogaert			
Ind.	**Date**	**Modifications**	**Visa Auteur**	**Visa RAQ**	**Visa Vérificateur**	**Visa Approb.**

Table of content

1 Introduction

1.1 Scope

This document reports on the VM2 physical performances for Light Yield, left/right asymmetry, and stability against vibration test.

1.2 Applicable Documents

1.3 Acronyms

DPD	Dual Pin photodiode
CsI(Tl)	Thallium-doped Caesium Iodide
CDE	CsI Detector Element
VM2	Validation Model N°2
LM2	Laboratory Model N° 2
ZIF	Zero Insertion Force

2 Test purpose

The test purpose is the determination of absolute Light Yield and light tapering of CDE's inserted in the VM2 like structure called LM2, and comparison of these quantities measured before and after vibration test at qualification level. The homogeneity of light Yield values validates the wrapping design and material choice. The reproducibility of measurements done before and after vibration test allows to validate the CAL mechanical structure concept and CDE/structure interface for CDE protection purpose, together with CDE stability against severe environmental conditions.

3 Tested articles

The LM2 structure is made of one layer of 12 cells filled with 12 CDE's (CsI(Tl) crystals with wrapping and DPD at each end) inserted in cells together with elastomeric cords. The cell geometry and closing system is the one used for VM2: a stack of plastic frame and elastomeric bumper holds the CDE in its position. Two Closeout Plates close the cells. Apertures in the Closeout Plates allow the Kapton cable to be connected to the ZIF connectors on test bench PCBs. CDE's are inserted such a way that Kapton cable escape toward the top (contacts are on the bottom side of the Kapton cable).

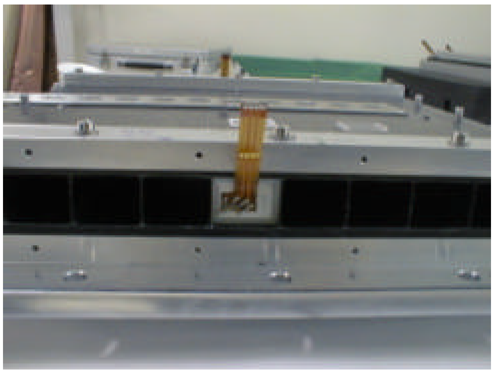
3.1 CDE's

CDE are composed of the following parts :

- CsI(Tl) scintillation crystal, a rectangular parallelepiped with chamfers on the edges along largest dimension
  Length = 333,0 mm ; Height = 19,9 mm and width = 26,7 mm.
- 2 Dual PIN Photodiodes at both ends of the CsI crystal.
  PIN diode external dimensions 22,3 mm x 15,0 mm x 1,8 mm.
  Small and Large diode areas are 25 mm^2 and 150 mm^2 (ratio = 6)

DPD are glued on CsI using optical silicon glue DC93-500 with primer
DPD are equipped with kapton cable

- Wrapping. Crystals are wrapped with VM2000 (3M) reflective material.



LM2 structure with one CDE inserted

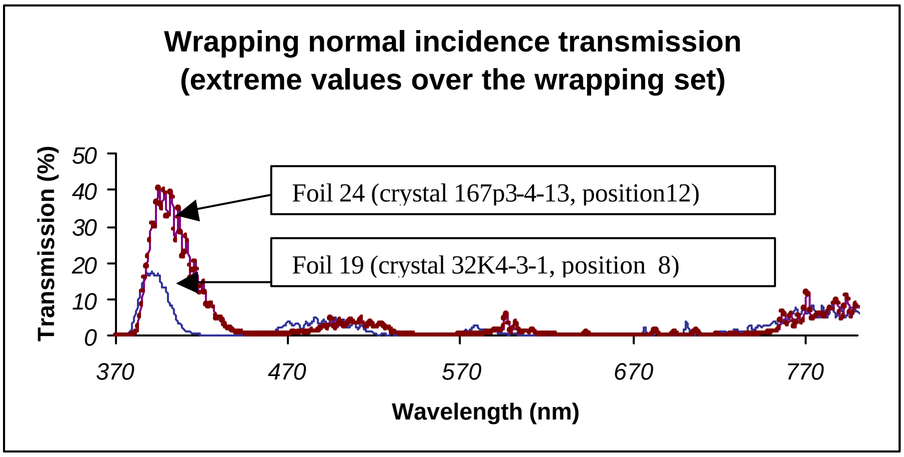
3.1.1 Crystal chamfering

Crystals have been properly chamfered (chamfer width 0.7 mm), as shown on the magnified view of crystal corners (left: before chamfering, right: after chamfering). On the scales, length between close tips is 0.5 mm.

Magnified views of crystal chamfers : left: from Amcrys, right: after chamfering.

3.1.2 Wrapping

Standard VM2000 film ("Visible Mirror film 2000") has been used to wrap the 12 crystals. No selection was applied on the wrapping material to narrow the range optical properties (reflectivity): its overall reflectivity varies by a few percent over the CsI(Tl) emission range (CsI(Tl) light emission peaks between 500 and 550 nm, and ranges between 350 and 750 nm) and this variation does not induce large scattering for Light Yield values, as shown below. The following graph displays the wrapping foil transmission between 370 and 800 nm, for normal light incidence angle. While reflection is the important parameter for light guiding purpose, transmission is shown which is directly correlated to reflection and straightforward to measure accurately.



Extreme values obtained by transmission scan of used VM2000 sheets at normal incidence angle

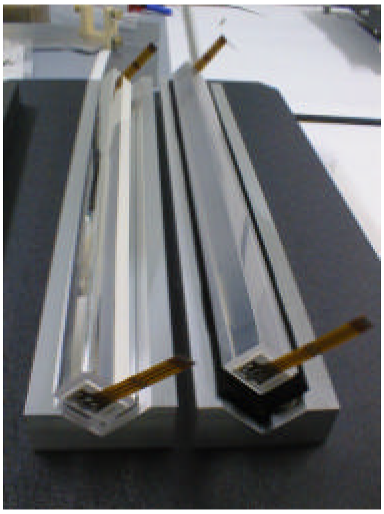
The two curves in the picture correspond to extreme values for transmission over the wrapping foil set used for VM2 crystals. The figure shows that film transmission stays below 5% (reflection > 95%) over most of the CsI(Tl) range, but above the low wavelength cutoff, which is also found to vary slightly. Notice that null transmission below 370 nm is due to the absorption of the film, and cannot be accounted for reflection.

3.1.3 CDE assembly

Picture shows a CDE (left) and a crystal with DPD's before wrapping (right) on V shaped supports which are used for crystal storage purpose. CDE's are wrapped using these V shaped supports, together with metallic rules to bend the wrapping on the upper crystal faces. The wrapping foil (333mm, ~ 97 mm) overlaps by a few mm, and is maintained closed up using adhesive tape in the ~6 mm wide space left free by the tooling (adhesive tape reference 850, 3M company, 50 microns thick). To ensure a very stable closure until CDE's are inserted in the cells, additional adhesive strips may be used and in present case a larger (25 mm width) strip was added, but it was not absolutely needed.

3.1.4 Interface with LM2 structure

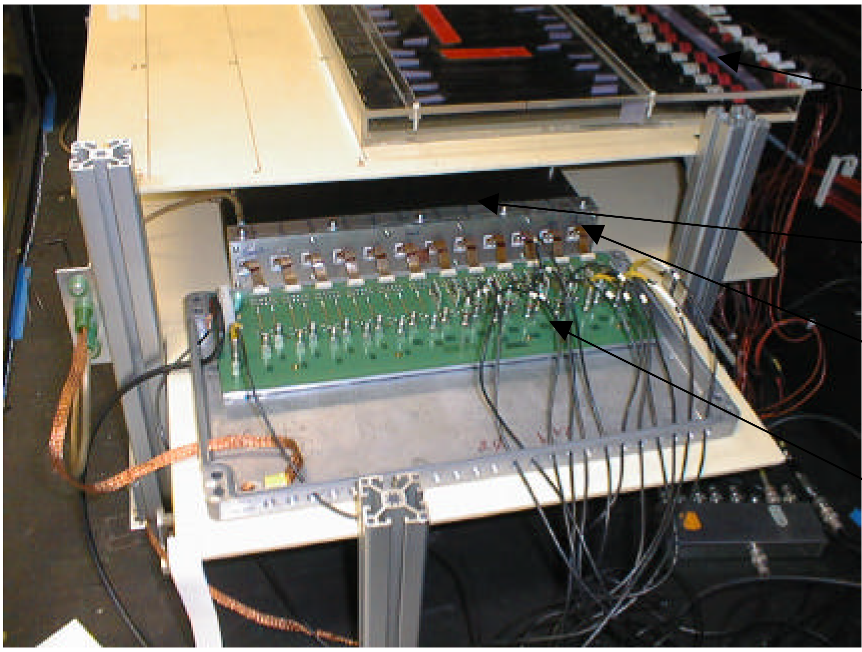
CDE's are held along the four corner by elastomeric cords. Each crystal end around the DPD is covered by an ivory plastic frame.



Crystals with DPD (right) and with wrapping (left)

4 Test bench

The Saclay test bench is used for the measurements. This test bench is described in detail elsewhere. Acquisition system allows event by event mode. Each event is triggered by a hodoscope made of two plastic scintillator layers localized above and below LM2. Hodoscope firing strip numbers and signals from DPD's are recorded event by event together with the temperature and humidity. Temperature is approximately constant (28° C within 2 °C) during all the runs, and no correction due to temperature effect is applied to the data.
Each channel is calibrated before the test measurement set using gamma rays at 59.5 keV (from 241 Am), 122.1 and 136.5 keV (from 57Co) interacting in DPD silicon (3.62 eV/pair).



Test bench picture

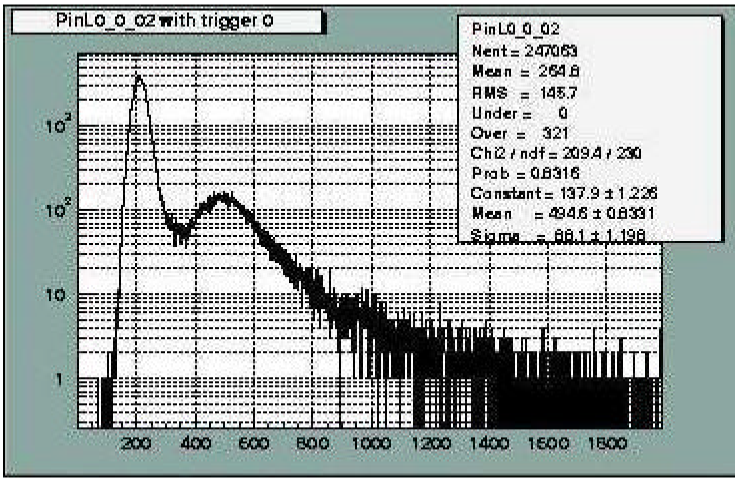
4.1 LM2 and hodoscope configuration

The following table summarizes the CDE compositions and positions in LM2. VM2000 wrapping foil are numbered according to there place in the used VM2000 roll.The two plastic hodoscope layers are placed at accurately determined positions (within approximately 1 mm) above and below crystals at positions 1 to 6 of the LM2 structure (Run 205 December 13, page 135 in log book) and in positions 7 to 12 (Run 206 December 14) successively.
After the vibration test, the same measurements are repeated (run 207: position 7 to 12, run 208 position 1 to 6) and measurements are compared.

Side B	position	PIN diode number	crystal	PIN diode number	VM2000 wrapping sample number	Crystal end	“side A
	1	52	167P3-40-2	58	36	Acetal (delrin) frame, color: ivory	
	2	72	32k4-5-1	70	18	“	
	3	67	32k4-4-8	69	20	“	
	4	71	32k4-2-7	68	22	“	
	5	64	32k4-4-1	75	28	“	
	6	53	32k4-5-5	56	40	“	
	7	51	32k4-4-2	54	34	“	
	8	80	32k4-3-1	82	19	“	
	9	79	32k-4-2-1	78	21	“	
	10	65	32k4-2-2	73	53	“	
	11	83	32k4-2-4	66	17	“	
	12	74	167p3-4-13	81	24	“	

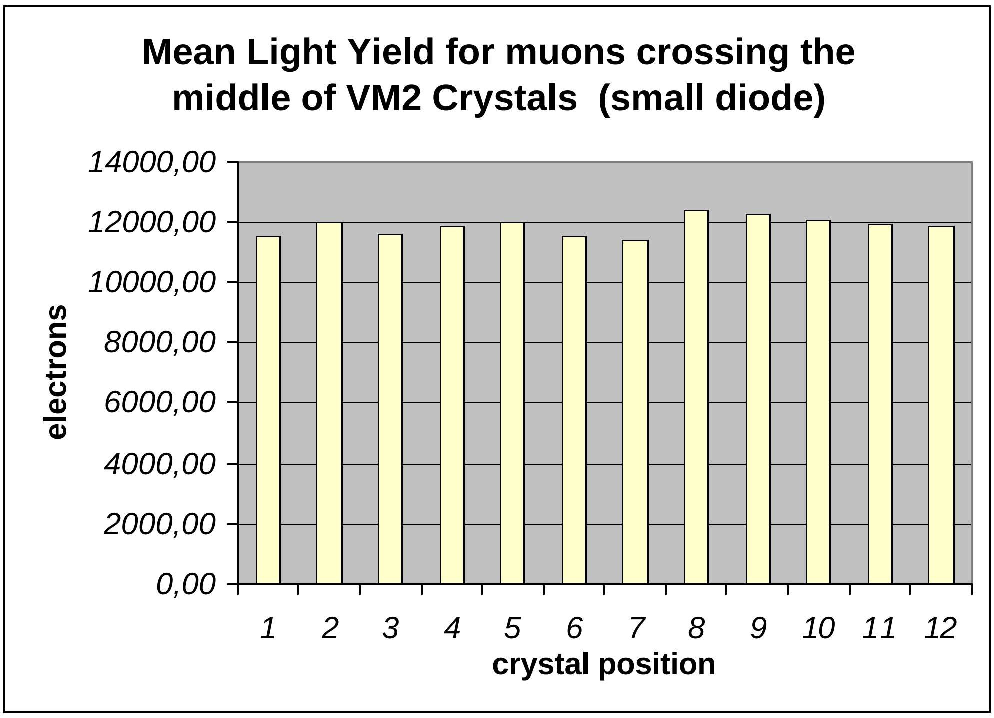
5 Light Yield For VM2 crystals

The following figure shows a typical cosmic muon spectrum obtained from the small diode. The first peak is the pedestal, and the bump is from muon energy loss. The pedestal peak and bump maximum positions are determined using a Gaussian and Landau function fit to the data respectively.



typical raw spectrum for small diode

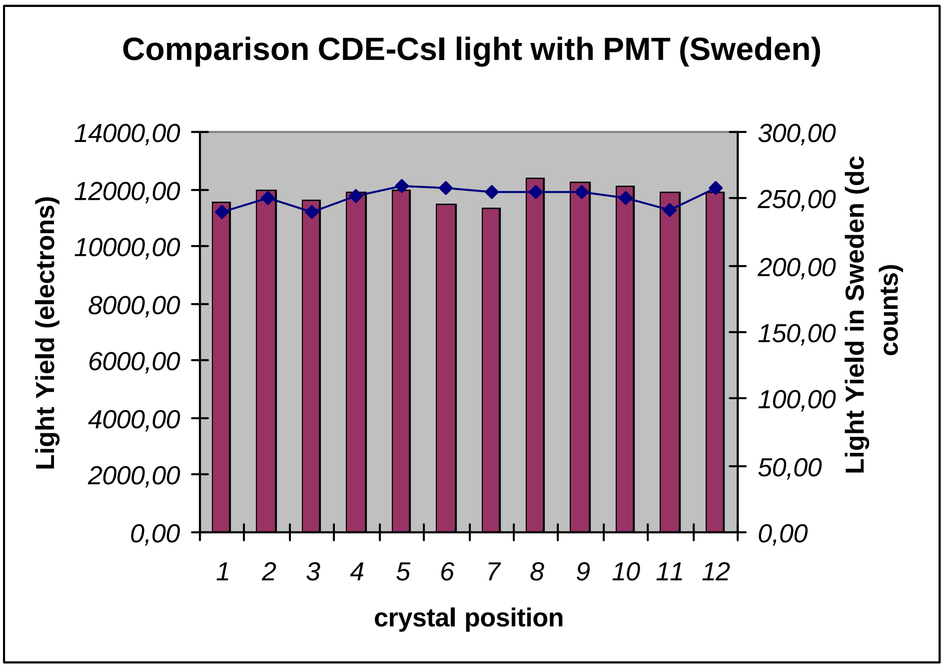
Using the calibration of each channel given in "Upgrade of the cosmic test bench for LM & VM2" by Ph.Bourgeois (Glast Ref : LAT-TD-00498-01,) table 2a and 2b, left and right signals are averaged and we obtain a mean light yield of 11862 electrons for muons crossing the crystal in the middle. Assuming the energy loss per muon is 13 MeV (from simulation taking into account the geometry of the set up) the light yield for small diodes is 912 e/MeV. Extreme values are 11366 and 12386 electrons, corresponding to 874 and 953 electrons/MeV at – 4.2 % and 4.4 % from the mean. These Light Yield values are obtained using a CAEN spectroscopy amplifier with shaping time of 3 microseconds, which corresponds to a peaking time of xxx microseconds. Measurements are performed around 28 °C.



Unfortunately, corresponding data are not available for large diodes due to a software problem. So the light yield ratio between small and large diode is still to be confirmed (ratio of areas is 6).

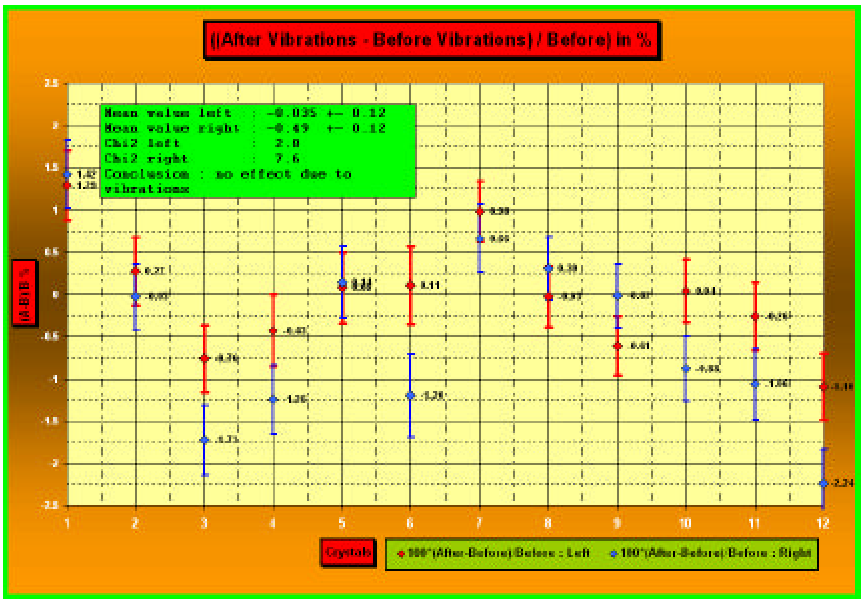
5.1 Light Yield comparison with Swedish data

The following figure displays the Light Yield comparison between present measurements (left scale, histogram) and measurement made in Sweden using PM tubes of large area at each crystal end and provider wrapping made of Tyvek and Aluminum(right scale, blue points). Absolute values cannot be compared, but the pattern can. One sees similar crystal to crystal light yield variation when measured with both systems. This good agreement provides an overall consistency check for both sets of measurements. It confirms the good crystal to crystal and CDE to CDE calibration accuracy, together with the homogeneity of the response using standard VM2000 film as wrapping material. It shows also that the LM2 structure with CDE /structure interface does not modifies the light output behavior of CDE's.

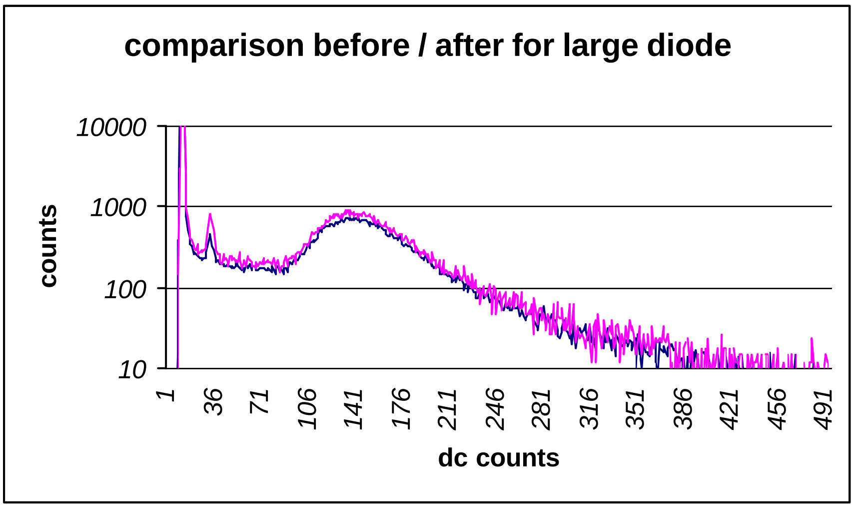


5.2 Light Yield comparison before after vibrations

The following figure shows the channel shift for each CDE, calculated as the ratio of the peak channel difference after –before the vibration test to the peak channel before the test. In the figure, red (blue) points are for left (right) PIN diodes. Error on peak determination from the fit is typically better than 1%. The maximum shift for light yield is found to be 2,2 %, which is found not significant. Notice that present data include electronics drifts over the test period (10 days). The mean value for the shift distribution is found compatible with zero for both left and right PIN diodes . So this comparison shows the excellent stability of CDE's over the vibration test.



Controls spectra for large diode recorded during data acquisition (but, without cuts and not in event by event mode: contributions from various z positions along the crystal length cannot be distinguished) drive the same conclusion, although they are less accurate: raw spectra recorded before and after vibration test are absolutely identical as shown below in a typical case.

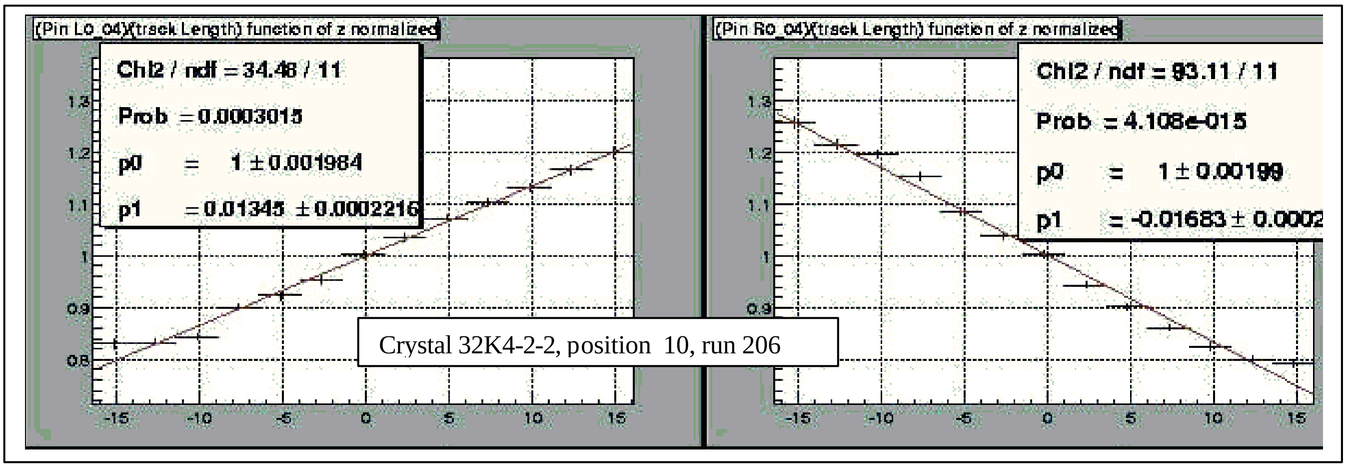


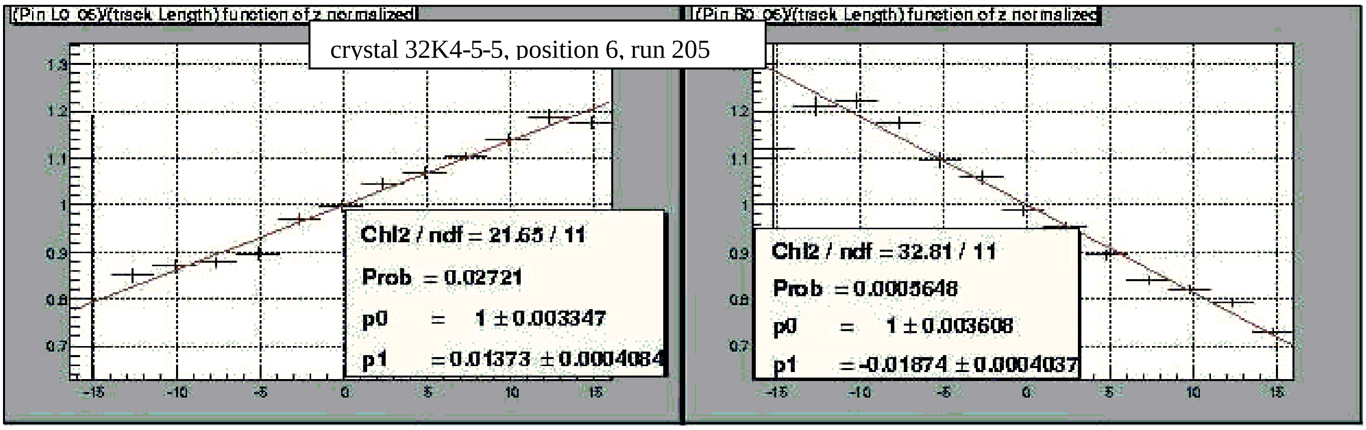
Typical control histograms obtained for large diode before and after vibration test

6 Light Tapering

Light measurements are made for 14 successive positions in the crystal, defined by the hodoscope strips (width 25 mm) perpendicular to the crystals above and below the crystals. The hodoscope (width = 25 x 14 = 350 mm) is larger than the crystal length (333 mm) and is centered (hodoscope center is between strips number 7 and 8) at the crystal center. The second strip and the 13th define interaction volumes centered at 29 mm from the two crystal ends, with 25 mm width. Fortunately measurements have been performed at same positions in Sweden (using a gamma ray source). The tapering values are calculated in Sweden as the ratio of the light yield obtained from farthest position (30 cm) to the one from nearest position (3 cm). In the following we adopt the same definition and calculate the light attenuation as the ratio of the light yield obtained at same positions, from farthest position (strip 13 or 2) to the one from nearest position (strip 2 or 13): this makes comparison between Swedish measurement and present ones straightforward.

Typical light attenuation curves are shown here below for left and right diodes. Lines through data points are linear fits to the data. Each point has horizontal bar with length equal to the hodoscope strip width (25 mm). The Y error bars are statistical only obtained from Landau fits.
Notice that in the following figure, as in Gentit's plots, , the crystal center is at 1.25 cm, strip number 2 is at -12.5 cm from the center on the X axis and strip 13 is the last one at 15 cm from crystal center.

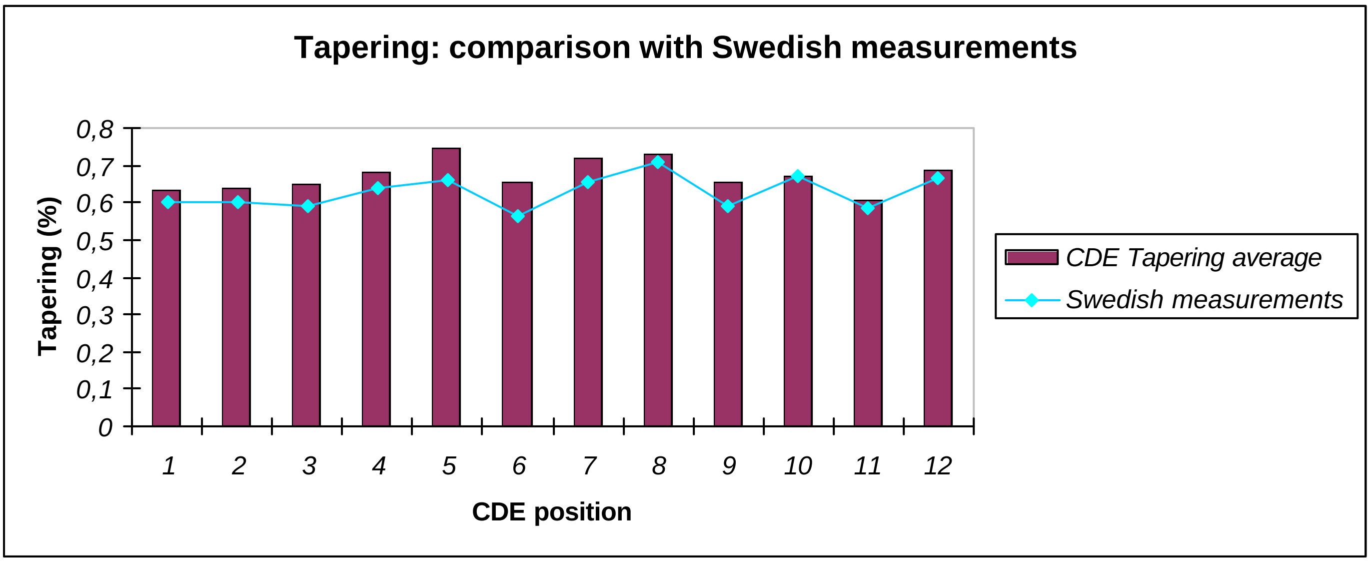




Typical light attenuation histograms for left and right diodes

6.1 Light Tapering values and comparison with Swedish data

The following picture compares light attenuations measured for CDE's in LM2 structure with the ones measured in Sweden for wrapped crystals (Tyvek wrapping, PMT read out). First, tapering measured values are of the same order for both sets of measurements (around 65%). Closer inspection shows that the tapering measured in present case in slightly different (mean tapering : 0.67) that in Swedish case (0.63). This can be account for difference in wrapping and crystal end optical properties in both experiments. However despite these large differences in light guiding and experiment set up, the tapering value is found quite stable. Tapering of all CDE's inside the structure are found inside the tapering acceptance range from 0.4 to 0.75. It is however rather near the upper bound of 0.75, and crystal light tapering could be slightly increased by the provider.
Second one sees a clear correlation between two sets of measurements. This provides an overall consistency check for measurement in Sweden and France, and shows their robustness and accuracy.
The compatibility of these measurements is an interesting feature: it means that the tapering measured in Amcrys Company and in Sweden using PMT and Tyvek wrapping are definitely relevant and should correspond (using a small correction factor) to the final tapering measured for CDE's inside the mechanical structure.

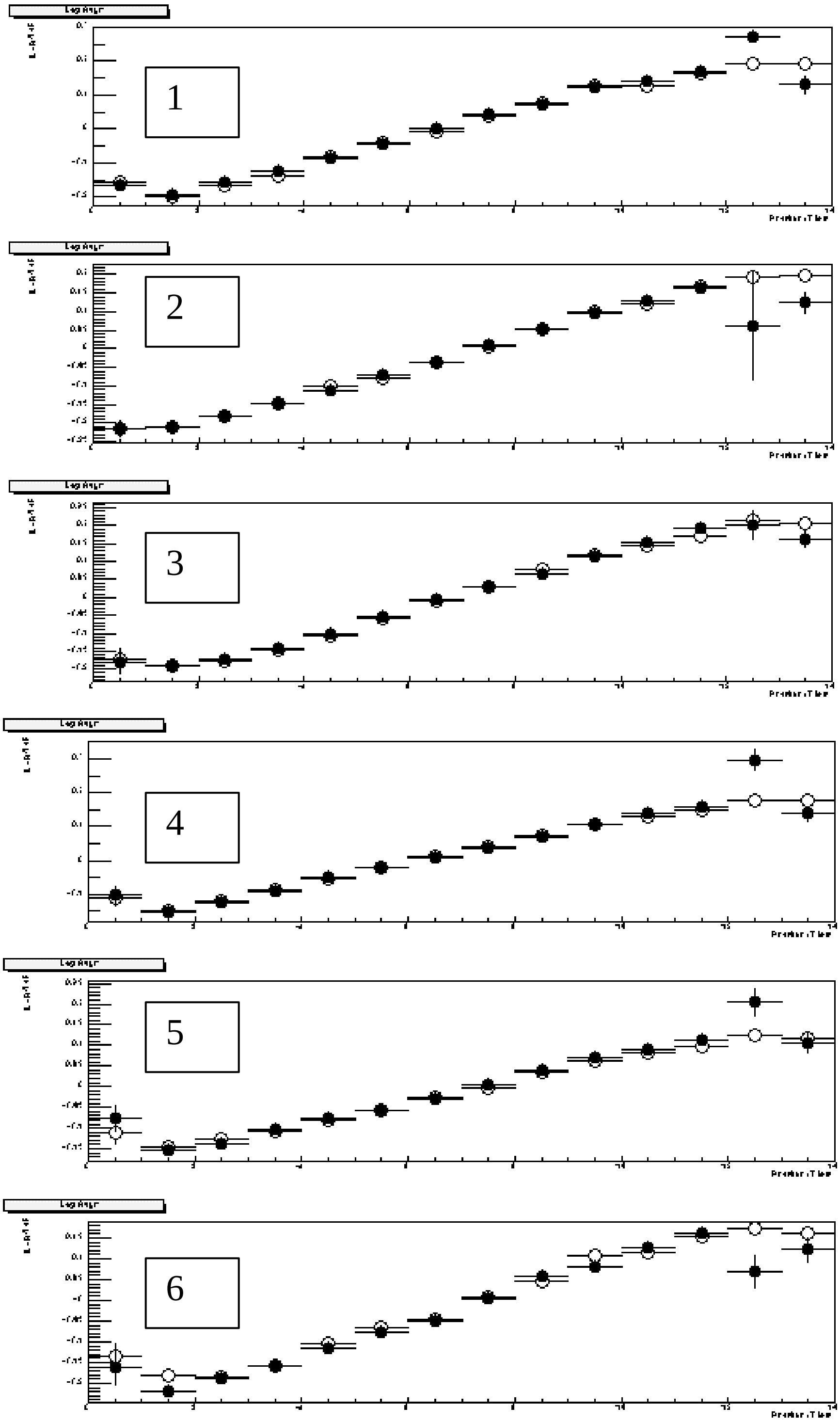


6.2 Tapering comparison before and after vibration test

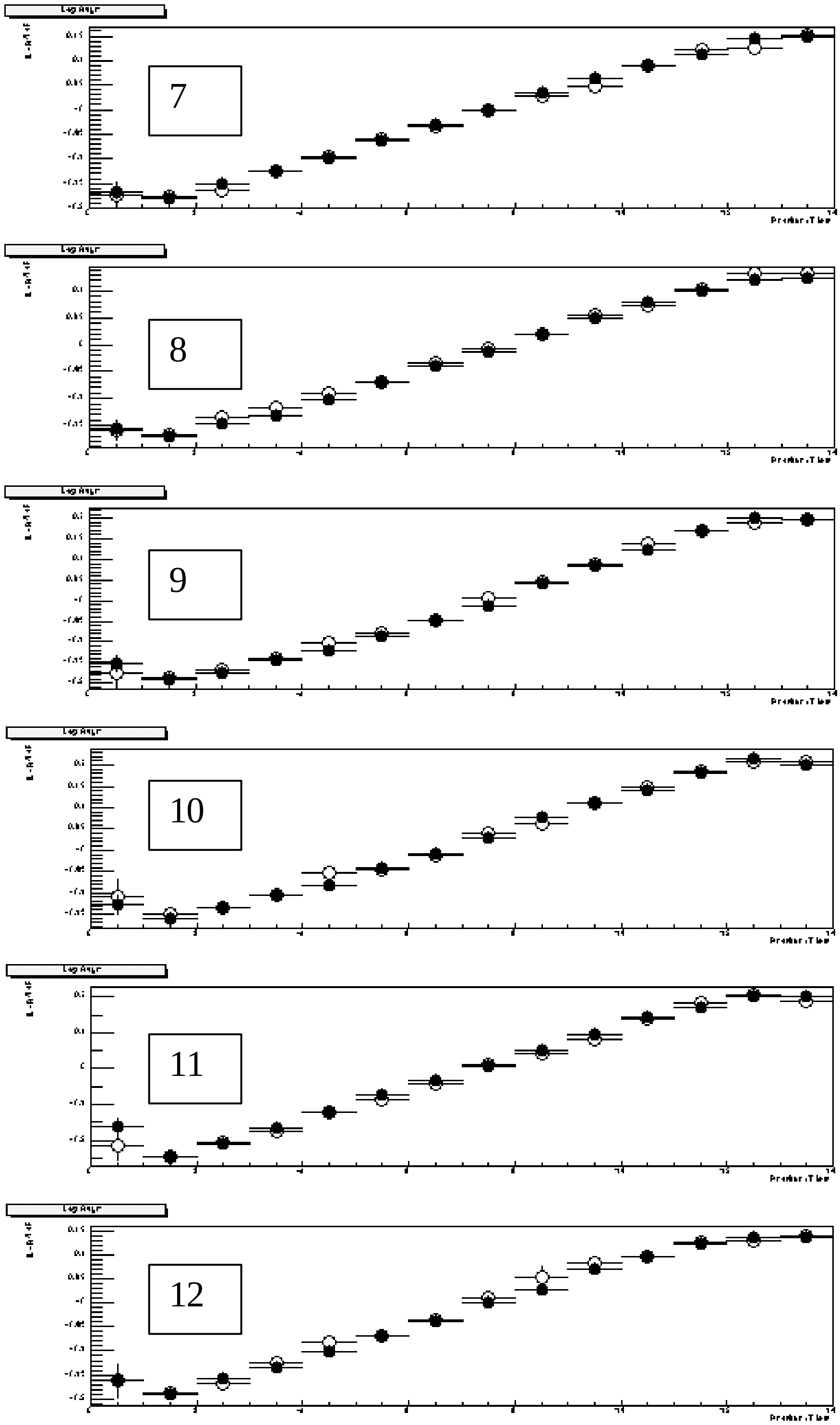
Light asymmetry (Left-Right)/(Left+Right) is plotted for small diodes of each CDE on following pictures. Open circles (black) correspond to measurements before (after) vibration. Each point has horizontal bar with length equal to the hodoscope strip width. The Y error bars are statistical only.

The two sets of measurements are identical: the vibration test did not induce any variation on the light tapering for any of the 12 crystals.

Notice that large deviations observed at strips 13 and 14 (actually in run 207) are due to problems encountered during data acquisition with electronics associated to these two strips, and should not be taken into account.



Light Asymmetry, crystals 1 to 6 (run 205 –208)



Light Asymmetry, crystals 7 to 12 (run 206 –207)

7 Conclusions

LM2 physical performances has been measured and are found inside specifications, for small diode light yield (900e/MeV), light tapering (from 61% to 73 %) and homogeneity of CDE to CDE response (+/- 5%).
It is shown that vibrations at qualification levels do not induce any change for these characteristics.
In addition excellent correlation is found between present measurements and Swedish ones, for CDE to CDE Light Yield. Tapering is found the same (at a few per cents approximation) in Sweden and for CDE's in LM2 in France despite the large differences in measurements setup.
Excellent agreement between all the collected data provide an overall consistency check for both set of data and proves the quality of crystal manipulation, quality of CDE wrapping system, and reliability of the test benches and measurements.

8 Annexe 1: test bench calibration

The following table gives the calibration for each channel, determined using standard gamma ray sources. Values for a and b are from "Upgrade of the cosmic test bench for LM & VM2" by Ph. Bourgeois Draft 07/12/01 (Glast Ref : LAT-TD-00498-01,) table 2a and 2b

		Right		Left	
Xtal #	**PIN**	**a (e/ch.)**	**b (e)**	**a (e/ch.)**	**b (e)**
1	A	36,48	2281,3	35,22	2561,7
2	A	36,53	2819,2	34,76	2517,1
3	A	32,64	2806,8	33,27	2312,3
4	A	34,14	2365,9	35,35	3086,7
5	A	33,84	3235,9	32,26	2838,0
6	A	31,53	2825,9	31,48	2171,8
7	A	36,39	2284,4	34,47	2663,4
8	A	34,53	2819,2	34,76	2517,1
9	A	32,64	2806,8	33,27	2312,3
10	A	34,14	2365,9	35,35	3086,7
11	A	33,84	3235,9	32,26	2838,0
12	A	31,53	2825,9	31,48	2171,8

9 Annexe 2 Test results for Light Yield before vibration (runs 205 and 206).

The following table gives the Light Yields and tapering slopes for small diodes before vibration. From Xavier Gentit Analysis, http://gentit.home.cern.ch/gentit/glastbc/runs/

position	crystal	Light Yield left	Light Yield right
1	167P3-40-2	246	261
2	32K4-5-1	258	263
3	32k4-4-8	266	283
4	32k4-2-7	252	275
5	32K4-4-1	271	271
6	32k4-5-5	285	286
7	32k4-4-2	252	250
8	32k4-3-1	275	270
9	32-4-2-1	294	295
10	32k4-2-2	260	279
11	324-2-4	268	268
12	167p3-4-13	301	295

10 Annexe 3 Test results for Light Yield after vibration (runs 207 and 208)

The following table gives the Light Yields and tapering slopes for small diodes after vibration. From Xavier Gentit analysis, http://gentit.home.cern.ch/gentit/glastbc/runs/

Position	Crystal	Light Yield left (channels)	Light Yield right (channels)
1	167P3-40-2	250	265
2	32K4-5-1	259	263
3	32k4-4-8	264	278
4	32k4-2-7	251	271
5	32K4-4-1	272	271
6	32k4-5-5	286	283
7	32k4-4-2	255	252
8	32k4-3-1	275	271
9	32-4-2-1	293	295
10	32k4-2-2	260	277
11	324-2-4	267	266
12	167p3-4-13	298	289

11 Annexe 4 Measured differences for Light Yield

The two following tables give the light yield values for left and right small PIN diodes, before and after the shake test, and the difference. Same analysis was performed on data in both cases by Xavier Gentit. The data presented here are extracted from http://gentit.home.cern.ch/gentit/glastbc/runs/

11.1 light yield left diode

position	crystal	Light Yield left before (channels)	Light Yield left after (channels)	after-before (channels)
1	167P3-40-2	246	250	4
2	32K4-5-1	258	259	1
3	32k4-4-8	266	264	-2
4	32k4-2-7	252	251	-1
5	32K4-4-1	271	272	1
6	32k4-5-5	285	286	1
7	32k4-4-2	252	255	3
8	32k4-3-1	275	275	0
9	32-4-2-1	294	293	-1
10	32k4-2-2	260	260	0
11	324-2-4	268	267	-1
12	167p3-4-13	301	298	-3

11.2 Light Yield right diode

Position	Crystal	Light Yield right before (channels)	Light Yield right after (channels)	after-before (channels)
1	167P3-40-2	261	265	4
2	32K4-5-1	263	263	0

3	32k4-4-8	283	278	-5
4	32k4-2-7	275	271	-4
5	32K4-4-1	271	271	0
6	32k4-5-5	286	283	-3
7	32k4-4-2	250	252	2
8	32k4-3-1	270	271	1
9	32-4-2-1	295	295	0
10	32k4-2-2	279	277	-2
11	324-2-4	268	266	-2
12	167p3-4-13	295	289	-6